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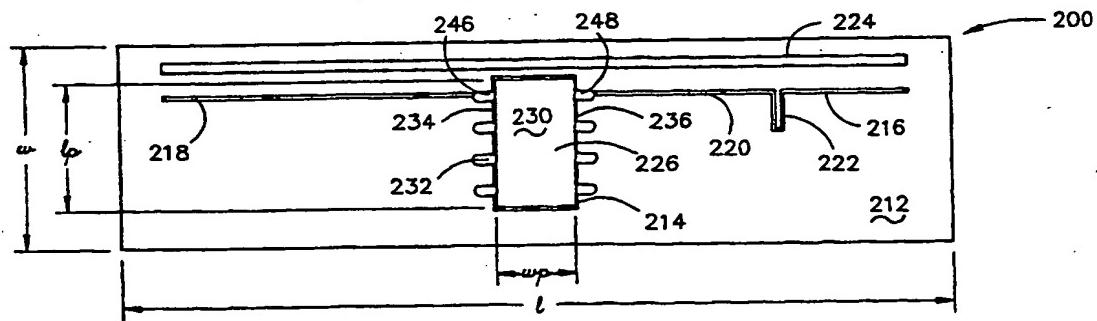
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(S1) International Patent Classification <sup>7</sup> :  G06K 19/077		A1	(11) International Publication Number: WO 00/43952  (43) International Publication Date: 27 July 2000 (27.07.00)
(21) International Application Number: PCT/US00/02042		(81) Designated States: JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).	
(22) International Filing Date: 21 January 2000 (21.01.00)			
(30) Priority Data: 09/235,243 22 January 1999 (22.01.99)		US	
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(54) Title: RFID TRANSPONDER



### (57) Abstract

A radio frequency identification integrated circuit (RFID IC) chip is packaged and oriented within a plastic molded package so that the RF characteristics of the packaged RFID IC are improved. The RFID IC may be packaged and oriented with respect to the antenna circuit so that the RF characteristics of the transponder are improved and/or the size (length, width, area, etc.) of the substrate is reduced. The packaged (RFID IC) may also be inverted and substantially and operably located within an aperture formed in the substrate of the RFID transponder to reduce the thickness of the transponder.

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## RFID TRANSPONDER

Cross-Reference to Related Applications

5        The present application is a continuation-in-part of U.S. Patent Application Serial No. 09/191,682 filed November 13, 1998 which claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Nos. 60/078,291 filed March 17, 1998 and 60/103,307 filed October 6, 1998, and claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Nos. 60/078,291 filed March 17, 10      1998, 60/103,307 filed October 6, 1998, and 60/072,317 filed January 23, 1998. Said U.S. Patent Application No. 09/191,682 and U.S. Provisional Application Nos. 60/078,291, 60/103,307, and 60/072,317 are herein incorporated by reference in their entirety.

Incorporation by Reference

15      The following U.S. Patents and Patent Applications are hereby incorporated herein by reference in their entirety:

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The following further documents are also incorporated herein by reference  
5 in their entirety:

IBM Technical Disclosure Bulletin

IBM Technical Disclosure Bulletin: Vol. 38 \_ 08, August 1995, page 17,  
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<u>Application</u>	<u>Filing Date</u>	<u>Attorney Docket</u>
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Field of the Invention

The present invention relates generally to radio frequency identification (RFID) systems, and more specifically to RFID transponders for use in RFID systems.

Background of the Invention

- 5                   Radio Frequency Identification (RFID) is becoming an important identification technology in applications such as inventory management, automotive toll debiting, security and personnel identification, factory automation, vehicle identification to name just a few. RFID systems utilize a radio frequency (RF) transmitter-receiver unit (base station or interrogator) to query an RFID transponder or tag located at a distance. The RFID transponder detects the interrogating signal and transmits a response signal comprising encoded data back to the interrogator's receiver. In this manner, RFID systems provide identification functions not found in identification technologies such as optical indicia (e.g., bar code) recognition systems. For example, an RFID system may employ RFID transponders containing read/write memory of up to several kilobytes. Further, several such RFID transponders may be read by a system at one time. These RFID transponders are readable at a distance and do not require direct line-of-sight view by the reading apparatus.
- 10                  When radio frequency integrated circuits such as radio frequency identification integrated circuits (RFID IC) are packaged in plastic packages such as Small Outline Packages (SOP), Miniature Small Outline Packages (MSOP), Small Outline Integrated Circuit (SOIC) packages, and Thin Shrinkable Small Outline Packages (TSSOP), for example, the RF characteristics of the RFID transponder are usually degraded due to discontinuities caused by the bonding wiring, materials, and geometry of the package. Further, the overall size of the RFID transponder usually becomes larger than it would be were the RFID IC directly attached to the substrate. As a result, the advantages of using packaged RFID IC's such as robustness, versatility, and availability may be outweighed by the poorer performance and increased size of the RFID transponder.
- 15
- 20
- 25
- 30

As a result, it would be advantageous to provide improved methods and apparatus for packaging radio frequency integrated circuits (e.g., RFID IC's) and for mounting packaged RFID IC's in RFID transponders so that the RF characteristics of the transponders are optimized and the size of the  
5 transponders is reduced.

#### Summary of the Invention

Accordingly, the present invention is directed to novel methods and apparatus for packaging radio frequency integrated circuits (RFIC) and in  
10 particular radio frequency identification integrated circuits (RFID IC) and mounting packaged RFID IC's in RFID transponders so that the RF characteristics of the transponders are improved and the size of the transponders is reduced.

An RFID transponder in accordance with a first aspect of the present  
15 invention includes an insulating substrate having an aperture formed therein and an antenna circuit (including an antenna and, optionally, impedance matching circuits) formed as an integral part of the substrate. A packaged RFID IC, including one or more leads for coupling the RFID IC to the antenna, is inverted and substantially and operably located within the aperture of the substrate so  
20 that the leads extend from the aperture and are coupled to the antenna.

In accordance with a second aspect of the present invention, a radio frequency integrated circuit (RFIC) chip such as a radio frequency identification integrated circuit (RFID IC) chip of an RFID transponder is packaged and oriented within a plastic package so that the RF characteristics of the packaged  
25 chip are improved. The RFID IC chip may also be packaged and orientated with respect to the antenna so that the RF characteristics of the RFID transponder are improved and/or the size (length, width, area, etc.) of the substrate is minimized.

It is to be understood that both the foregoing general description and the  
30 following detailed description are exemplary and explanatory only and are not restrictive of the invention claimed. The accompanying drawings, which are

incorporated in and constitute a part of the specification, illustrate an embodiment of the invention and together with the general description, serve to explain the principles of the invention.

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#### Brief Description of the Drawings

The numerous objects and advantages of the present invention may be better understood by those skilled in the art by reference to the accompanying figures in which:

10 FIG. 1 is a block diagram depicting a typical RFID system;  
FIG. 2 is a top plan view of an RFID transponder in accordance with an exemplary embodiment of the present invention having a simple dipole antenna;

FIG. 3 is a top plan view of an RFID transponder in accordance with an exemplary embodiment of the present invention having a meander dipole antenna;

15 FIG. 4 is a partial cross-sectional side elevational view of the RFID transponder shown in FIG. 1;

FIG. 5 is an isometric view of the RFID transponder shown in FIG. 1;  
FIG. 6 is a top plan view of an RFID transponder in accordance with an exemplary embodiment of the present invention having a linearly polarized patch antenna;

20 FIG. 7 is a top plan view of an RFID transponder in accordance with an exemplary embodiment of the present invention having a circularly polarized patch antenna;

FIGS. 8 and 9 are top plan views of RFID transponders in accordance with a further exemplary embodiment of the present invention;

25 FIG. 10 is a partial cross-sectional side elevational view of the RFID transponder shown in FIG. 6;

FIGS. 11, 12 and 13 are block diagrams illustrating interconnection of the RFID IC chip to the leads of a plastic-molded package; and

30 FIG. 14 is a partial cross-sectional side elevational view of a prior art RFID transponder having a packaged RFID IC.

Detailed Description of the Invention

Reference will now be made in detail to the presently preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. As used herein in the specification and claims, references to vertical relationships between elements, i.e., top, bottom, up, down, inverted, etc., are relative to the surface of the substrate of the RFID transponder.

Referring now to FIG. 1, a typical RFID system is shown in which RFID transponders of the present invention may be employed. The RFID system 100 includes an interrogator or base station 112 communicating an RF signal to an RFID transponder 114. The interrogator 112 preferably includes RF transmitter and a receiver sections 116 & 118 for providing two way communication with the RFID transponder 114. The transmitter section 116 preferably includes an RF source 120 and RF amplifier 122 which send RF power to an antenna 124. The transmitter section 116 transmits an RF signal with a transmitter carrier frequency. The transmitter carrier also has a transmitting carrier frequency bandwidth referred to as a transmitting bandwidth. The transmitting bandwidth is preferably wide enough to transmit data at a desired rate.

The RFID transponder 114 comprises an antenna 126 and an RFID circuit 128 including an RF processing section (typically referred to as a front end) 130 and a signal processing section 132. The front end 130 can be any known front end design used with an antenna. Examples of front ends are well known. See, for example, the Hewlett Packard "Communications Components GaAs & Silicon Products Designer's Catalog" (i.e., page 2-15) which is herein incorporated by reference in its entirety. A typical front end is also described in U.S. Patent Application Serial No. 08/790,639 to Duan, et al. filed January 29, 1997 which is herein incorporated by reference in its entirety. The signal processing section 132 may include logic circuits and memory for processing and storing information.

The present invention provides methods and apparatus for packaging

RFID IC's which include the front end and signal processing section of the RFID transponder, and mounting the packaged RFID IC's in RFID transponders so that the RF characteristics of the transponders are improved and the size of the transponders is reduced.

Referring now to FIGS. 2 through 10, exemplary RFID transponders in accordance with the present invention are shown. The RFID transponders 200 include an insulating substrate 212 which is preferably formed of a rigid dielectric material such as FR-4 epoxy resin, phenolic, a ceramic, etc., or, alternatively, a flexible material such as polyimide, polyester, or the like. An aperture 214 may be formed in the substrate 212 for receiving a packaged RFID IC 226. The aperture 214 may extend completely through the substrate 212 (e.g., a hole), or, alternatively, only partially through the substrate 212 (e.g., a recess). As shown in FIGS. 2 through 5, the substrate 212 may be rectangular in shape and may have a length (*l*) and a width (*w*). However, it should be appreciated that the substrate may have other geometric or irregular shapes (i.e., circular, oval, square, triangular, curvilinear, etc.) without departing from the scope and spirit of the invention.

An antenna circuit 216 is integrally formed on the substrate 212. Preferably, the antenna circuit 216 consists of a thin pattern (typically 18 to 35 microns thick) formed of a conductive metal such as copper. This pattern may be formed by plating, adhering or screening a thin layer of copper (or other conductive metal) onto the substrate 212. The layer is then etched to form the desired geometric configuration of the antenna circuit 216.

Depending on the RF properties desired, the antenna circuit 216 of the present invention may employ any of a large number of different antennas having various configurations and geometries (i.e., monopole, dipole, folded dipole, loop, slot, coil, spiral, meander, patch, etc.). For example, as shown in FIGS. 2 and 5, the antenna circuit 216 may comprise a simple dipole antenna consisting of dipole elements or traces 218 & 220. Alternatively, as shown in FIG. 3, the antenna circuit 216 may comprise a meander dipole antenna. Like the simple dipole antenna shown in FIGS. 2 and 5, the meander dipole antenna

may also comprise dipole elements or traces 218 & 220. However, the dipole elements 218 & 220 of the meander dipole antenna are bent in a "meander" pattern reducing the antenna's overall length. Further, as shown in FIGS. 6 through 9, the antenna circuit 216 may comprise a patch antenna including a 5 patch element 254 and a conducting ground plane 256. The conducting ground plane 256 may comprise a layer of conductive metal (e.g., copper) formed (i.e., by plating, adhering or screening, etc.) on the side of the substrate 212 opposite the pattern. The substrate 212 spaces the antenna's radiating element (e.g., patch element 254, or, alternatively, other structures such as dipole elements, 10 etc. (not shown)) from the ground plane 256. It should be recognized that reconfiguration of any of the antenna circuits 216 shown herein, or substitution of other types of antennas by one skilled in the art would not depart from the scope and spirit of the invention.

One or more impedance adjustment elements 220 may likewise be 15 integrally formed on the substrate 212 to modify the impedance of the antenna circuit 216. The impedance adjustment elements 220 may be, for example, lumped circuit elements, distributed microwave circuit elements, or parasitic elements that are electromagnetically coupled to the antenna (i.e., not electrically connected). As shown in FIG. 2, the antenna circuit 216 may, for 20 example, include a tuning stub 222 having a length and width adjusted to tune the impedance of the antenna. The tuning stub 222 acts as a two conductor transmission line and may be terminated either in a short-circuit or open-circuit. A short circuited stub acts as a lumped inductor while an open-circuit stub acts as a lumped capacitor. The magnitude of the reactance of the tuning stub 222 is 25 affected by the stub's length, width, and spacing. Similarly, one or more impedance loading bars 224 may be integrally formed on the substrate 212 adjacent to the antenna in the same manner. The impedance loading bars 224 are electromagnetically coupled to the antenna to modify its impedance. Use of impedance adjustment elements such as tuning stubs and impedance loading 30 bars to adjust the impedance of an antenna is described in detail in U.S. Patent Application Serial No. 08/790,639 to Duan et al., filed January 29, 1997, which is

herein incorporated by reference in its entirety. Further, as shown in FIGS. 6 through 9, the antenna circuit 216 may include impedance matching circuits (i.e., microstrip lines, or the like) 258 & 260. These circuits 258 & 260 which are connected to the packaged RFID IC 226, may interconnect the RFID IC 226 to the radiating element of the antenna circuit 216 (e.g., impedance matching circuit 260) to carry RF signal and energy from the RFID IC 226 to the antenna (e.g., patch antenna element 254) and/or from the antenna 254 to the RFID IC 226. Preferably, the circuits 260 have a length and width chosen to at least partially match the impedance of the antenna 254 and the RFID IC 226.

Referring now to FIGS. 2 through 10, the packaged radio frequency identification integrated circuit (RFID IC) 226 is mounted to the substrate 212 and electrically interconnected to the antenna circuit 216. The packaged RFID IC 226 preferably comprises an RFID IC chip 228 encapsulated within a plastic-molded package 230. The package 230 may be a single in-line package (SIP), dual in-line package, or flat pack package (shown). Typical flat pack IC packages which may be utilized by the present invention include, but are not limited to Small Outline Package (SOP), Miniature Small Outline Package (MSOP), Small Outline Integrated Circuit (SOIC), Plastic Ball Grid Array (PBGA), Thin Quad Flat Pack (TQFP), Low Profile Quad Flat Pack (LQFP), Metric Quad Flat Pack (MQFP), Plastic Quad Flat Pack (PQFP), Plastic Leaded Chip Carrier (PLCC), Thin Shrinkable Small Outline Package (TSSOP), Shrinkable Small Outline Package (SSOP), Quad Small Outline Package (QSOP), Plastic Dual Inline Package (PDIP), SC 70, SC-79, Small Outline Transistor (SOT-23, SOT-143), and Small Outline Diode (SOD-323) packages. Preferably, the package 230 includes a plurality of external leads or pins 232 which electrically couple the packaged IC 230 to the copper pattern or traces formed on the substrate 212. The leads or pins 232 may be arranged in rows along all four sides 234, 235, 236 & 237 of the package 230 (i.e., a quad-flat-pack package), or, alternatively, only on opposite sides 234 & 236 of the package 230 (i.e., an MSOP, or the like) depending on the type of package 230 employed. The leads 232 may be electrically connected to contacts 238 & 240 on the RFID IC chip 228 via

connectors 246 & 248 formed using conventional techniques such as wire bonding or the like (see FIGS. 4 and 10). The leads 232 may then be soldered to the circuit (e.g., antenna circuit 216) formed on the substrate 212 to, for example, connect the contacts 238 & 240 of the RFID IC chip 228 to the antenna circuit 216 (i.e., directly to the antenna, or, alternatively, to impedance adjustment elements 220 such as impedance matching circuits 258 & 260).

- Packaged RFID IC's have in the past been mounted to a substrate so that the body of the RFID IC package is completely above the upper surface of the substrate. A typical prior art RFID transponder having a flat-pack packaged 5 RFID IC is shown in FIG. 14. The packaged RFID IC 312 of the RFID transponder 300 includes a generally rectangular body 314 having a top surface 316, a bottom surface 318, first and second side surfaces 320 & 322, and first and second end surfaces (not shown). Preferably, the package includes a plurality of leads 324 which extend outwardly from each side surface 320 & 322.
- 10 The leads 324 may be generally "S" or "Z" shaped in profile so that they extend downwardly past the bottom surface 318 of the RFID IC's body 314. When the RFID IC 312 is mounted to the substrate 326, the leads 324 may be soldered 15 to antenna elements 328 and/or other circuits 330 of substrate 326 so that the body 314 of the RFID IC 312 is supported above the substrate 326 and 20 antenna elements 328 and/or circuits 330. The RFID transponder 300 may have a thickness (*t*) which comprises the combined thicknesses of the packaged RFID IC 312, the substrate 326, the antenna elements 328 and/or circuits 330 and/or the space between the RFID IC body 314 and the substrate 326 or antenna 25 elements 328 and/or circuits 330, if any.
- As shown in FIGS. 2 through 10, and particularly in FIGS. 4, 5, and 10, the packaged RFID IC 226 of the RFID transponder 200 may be inverted (compared to the orientation of the RFID IC 314 of the prior art RFID transponder 300 shown in FIG. 8) and substantially located within the aperture 214 of the substrate 212. This orientation reduces the thickness (*t*) form factor of 30 the RFID transponder 200 by eliminating the space between the RFID IC and the substrate of the prior art RFID transponder (314, 326 & 300 in FIG. 8), and

reducing the thickness of the RFID IC 226 by an amount equal to the thickness of the RFID IC 226 contained within the aperture 214 of the substrate 212.

Preferably, the leads 232 of the RFID IC package 230 extend upwardly from the aperture 214 and are coupled to the antenna circuit 216 (and/or other circuits formed on the substrate 212). The leads 232 may be bent (i.e., an MSOP or the like) so that they are somewhat "S" or "Z" shaped and have an end extending over the edge of the aperture 214. Alternatively, the leads 232 may be straight (i.e., a SIP, a DIP, etc., not shown). The leads 232 may support the packaged RFID IC 226 within the aperture 214 and may engage the antenna circuit 216 (and/or other circuits) formed on the substrate 212. Preferably, the leads 232 may be soldered to the antenna circuit 216 (and/or other circuits) to secure the RFID IC 226 to the substrate 212. As shown in FIG. 4, an encapsulant 242 may be applied to secure the packaged RFID IC 226 within the aperture 214 and to protect the lead/circuit connections 244.

Referring now to FIGS. 11, 12, and 13, radio frequency integrated circuit (RFIC) chips such as RFID IC 226 may be packaged and orientated with respect to the antenna circuit 216 so that the RF characteristics of the RFID transponder are optimized. The RFID IC package 230 may be generally rectangular in shape and may have a length ( $l_p$ ) and a width ( $w_p$ ). An RFID IC chip 228 is encapsulated within the package 230. The RFID IC chip 228 includes first and second antenna contacts or pads 238 & 240 (e.g., signal pad and a ground pad) which may be electrically connected to first and second leads 250 & 252 of the package's lead frame via connectors such as wire bonds 246 & 248. Preferably, the wire bonds 246 & 248 are formed via conventional wire bonding methods.

As shown in FIGS. 2, 8 and 11, the first lead (Pin 1) 250 of the packaged RFID IC 226 may extend from the first side 234 of the package 230. The first lead 250 may be connected to the antenna circuit 216 (i.e., dipole element 218 shown in FIG. 2, or, alternatively, impedance matching circuit 258 shown in FIG. 8). Similarly, a second lead (Pin 8) 252 may extend from the second side 236 of the package 230 opposite the first, where it may likewise be attached to the antenna circuit 216 (i.e., dipole element 220 shown in FIG. 2, or, alternatively,

impedance matching circuit 260 shown in FIG. 8).

Alternatively, as shown in FIGS. 3, 9, and 12, the first lead (Pin 2) 246 and the second lead (Pin 3) 248 may both be on the same side 234 of the package 230 where they may be attached to the antenna circuit 216 (i.e., the 5 first lead 250 may be connected to the dipole antenna element 218 and the second lead 248 may be attached to the dipole antenna element 220 as shown in FIG. 3, or the first lead 250 may be attached to impedance matching element 258 and the second lead 252 may be attached to impedance matching element 260 as shown in FIG. 9).

10        Alternatively, as shown in FIG. 6, 7, and 13, the first lead (Pin 1) 250 may extend from a first side 234 of the package 230. The first lead 250 may be connected to the antenna circuit 216 (i.e., impedance matching circuits 260 shown in FIGS. 6 and 7). Similarly, the second lead (Pin 16) 252 may extend from a second side 235 of the package 230 where it may be attached to the 15 antenna circuit 216 (i.e., impedance matching circuits 258 shown in FIGS. 6 and 7). Preferably, the first and second sides 234 & 235 form a corner of the package 230. The first and second leads 250 & 252 may be positioned one on each side of the corner at a substantially right angle to each other.

It should be appreciated that in accordance with the second aspect of the 20 invention, packaged RFID IC's may be mounted in the inverted fashion in accordance with the first aspect of the present invention shown in FIGS. 2, 3 and 6, or, alternatively in the conventional manner (so that body of the RFID IC package is completely above the upper surface of the substrate of the RFID transponder) as shown in FIG. 14.

25        Because the frequency of an RFID system (i.e., RFID system 100 shown in FIG. 1) is typically very high so that the wavelength is very short (i.e., within the microwave range), it is desirable to maximize coupling of external RF energy into the RFID IC chip 228 (especially were the RFID transponder 200 is passive).

The introduction of any discontinuity in the line connecting the antenna circuit 30 216 and antenna contacts 238 & 240 will cause a change in signal strength or attenuation which will change the function of the RFID IC chip 228 and

performance of the RFID transponder 200. Consequently, the lines (e.g., leads 250 & 252 and wire bonds 246 & 248) interconnecting the antenna circuit 216 and antenna contacts 238 & 240 are preferably symmetrical, short in length, and have very few discontinuities so coupling of the RF signal into the RFID IC chip 228 is maximized.

The arrangement and orientation of the RFID IC chip 228, package 230, and wire bonds 246 & 248 in accordance with the present invention as shown in FIGS. 11, 12, and 13 result in less discontinuity in the interconnection, which reduces the amount of reflections and spurious radiations, improving the radiation efficiency when connected to an antenna and reducing the mismatch loss and radiation loss when connected to a circuit. The RFID IC chip 228 is preferably oriented within the package 230 so each of the antenna contacts 238 & 240 is substantially adjacent to the lead 250 & 252 to which it is bonded. This orientation allows the package 230 to have a shorter, smoother wire bonds connecting the contacts 238 & 240 to the leads 250 & 252. Shorter wire bonds 246 & 248 are desirable because the lengths of the wire bonds 246 & 248 and leads 250 & 252 contribute to the inductance of the antenna circuit 216. Further, when added together, impedance contributed by the wire bonds 246 & 248 and leads 250 & 252 may become a significant portion of the antenna circuit's total impedance. Preferably, the orientation also allows the wire bonds 246 & 248 to have similar lengths.

The lines (e.g., leads 250 & 252 and wire bonds 246 & 248) interconnecting the RFID IC 228 to the antenna circuit 216 preferably have similar cross-sections, and good conductivity (i.e., are not resistive). In this manner, a smoother transition is provided for the RF wave (e.g., microwave) between the antenna circuit 216 and the antenna contacts 238 & 240 thereby providing improved RF characteristics.

Orientation of the RFID IC 228, package 230, and wire bonds 246 & 248 in accordance with the present invention also prevents crossover, bending or kinking of the wire bonds 246 & 248. Crossovers introduce cross-talk and additional parasitic capacitance or inductance which may degrade performance

- of the RFID transponder 200. Bending or kinking introduces discontinuities in the RF wave (e.g., microwave) structure. Such discontinuities are sources of leakage, radiation loss, etc. which reduce the efficiency of the RFID transponder 200. For passive RFID transponders 200, wherein the transponder 200 does not
- 5 have its own power source, the RFID IC 228 collects power from the RF field via the antenna circuit 216. Thus, the efficiency of the lines (e.g., leads 250 & 252 and wire bonds 246 & 248) transmitting RF power between the antenna circuit 216 and the RFID IC 228 helps prevent a reduction in power available to the RFID IC 228.
- 10 The orientation of the RFID IC 228, package 230, and wire bonds 246 & 248 may also allow the size (e.g., length ( $l$ ), width ( $w$ ), or total area) of the substrate 212 of the RFID transponder 200 to be minimized. How the packaged RFID IC 226 is oriented on the substrate 226 is a function of the size and shape of the package 230 (i.e., whether  $l_p > w_p$ ,  $l_p < w_p$ , or  $l_p = w_p$ ), the dimension (i.e.,
- 15 length ( $l$ ), width ( $w$ ), or overall area) of the substrate 212 to be minimized, and the position and orientation of the packaged RFID IC 226 on the substrate. For example, as shown in FIGS. 2, 5 and 11, the antenna circuit 216 may comprise a simple dipole antenna which includes a first dipole element 218 and a second dipole element 220 formed on the surface of the substrate 212 on each side of
- 20 the packaged RFID IC 226. Preferably, as shown in FIG. 11, the first lead (Pin 1) 250 extends from the first side 234 of the package 230 and is connected to the first antenna circuit element 218 while the second lead (Pin 8) 252 extends from the second side 236 of the package 230 opposite the first and is attached to the second antenna circuit element 220. This allows the package 230 to be
- 25 positioned on the substrate 212 so that the length ( $l_p$ ) of the package 230 is perpendicular to the dipole elements 218 & 220 of the antenna circuit 216, and the length ( $l$ ) of the substrate 212 while the width ( $w_p$ ) of the package 230 is parallel to the dipole elements 218 & 220 and width ( $w$ ) of the substrate 212. Thus, referring to FIGS. 2 and 5, wherein the package's width ( $w_p$ ) is shorter than
- 30 its length ( $l_p$ ), the length ( $l$ ) of the substrate 212 may be reduced. Alternately,

wherein the package's width ( $w_p$ ) is longer than its length ( $l_p$ ), the width ( $w$ ) of the substrate 212 may be reduced.

Similarly, as shown in FIGS. 3 and 12, the antenna circuit 216 may comprise a meander dipole antenna which includes a first dipole element 218 and a second dipole element 220 formed on the surface of the substrate 212 adjacent to the packaged RFID IC 226. Preferably, as shown in FIG. 12, the first lead (Pin 2) 246 and the second lead (Pin 3) 248 are both located on the same side 234 of the package 230. The first lead 246 may be connected to the first dipole element 218, and the second lead 248 attached to the second dipole element 220. This allows the package 230 to be positioned on the substrate 212 so that the length ( $l_p$ ) of the package 230 is parallel to the longitudinal length of the antenna 216 and length ( $l$ ) of the substrate 212 while the width ( $w_p$ ) of the package 230 is perpendicular to the longitudinal length of the antenna 216 and width ( $w$ ) of the substrate 212. Thus, wherein the package's width ( $w_p$ ) is longer than its length ( $l_p$ ), the length ( $l$ ) of the substrate 212 may be reduced. Alternately, wherein the package's width ( $w_p$ ) is shorter than its length ( $l_p$ ), the width ( $w$ ) of the substrate 212 may be reduced.

Turning now to FIGS. 6, 7, 8 and 9, the antenna circuit 216 may further comprise a patch antenna including a patch element 254, one or more impedance matching circuits 258 & 260, and a conducting ground plane 256. The patch antenna may be a linearly polarized patch antenna as shown in FIGS. 6, 8, and 9, or, as shown in FIG. 7, a circularly polarized patch antenna. As shown in FIGS. 6, 7 and 13, the first lead (Pin 1) 250 and second lead (Pin 16) 252 may be arranged at a right angle to each other at a corner of the package 230. Similarly, as shown in FIGS. 8 and 11, the first lead (Pin 1) 250 may extend from the first side 234 of the package 230 while the second lead (Pin 8) 252 extends from the second side 236 of the package 230 opposite the first. Further, as shown in FIGS. 9 and 12, the first lead (Pin 2) 246 and the second lead (Pin 3) 248 are both located on the same side 234 of the package 230. By altering the lead (pin) 232 arrangement in this manner, the packaged RFID IC 226 may be oriented and mounted on the substrate 212 and bonded to the antenna circuit

216 to provide a smoother transition for the RF wave (e.g., microwave) between the antenna and the RFID IC 226 and/or to reduce or minimize the surface area of the RFID transponder 200.

Various modifications may be made in and to the above described 5 embodiments without departing from the spirit and scope of the invention. For example, modifications and changes may be made in the configuration of the RFID IC, the placement of the RFID IC on the substrate, the antenna circuit geometry, substrate material, package material, or package geometry. Further, use of the RFID transponder is directed to a wide variety of applications 10 including, but not limited to, airline baggage (i.e., luggage, freight, and mail), postal service, manufacturing, inventory control, personnel security, and the like.

It is believed that the present invention and many of its attendant advantages will be understood by the foregoing description, and it will be apparent that various changes may be made in the form, construction and 15 arrangement of the components thereof without departing from the scope and spirit of the invention or without sacrificing all of its material advantages. The form herein before described being merely an explanatory embodiment thereof, it is the intention of the following claims to encompass and include such changes.

Claims

What is claimed is:

1. A packaged radio frequency circuit, comprising:  
a lead frame package having at least one lead for coupling the packaged radio  
frequency circuit to an antenna circuit;  
5. a radio frequency circuit chip contained within said lead frame package, said  
circuit chip including an antenna contact; and  
a connector electrically connecting the antenna contact and lead;  
wherein the antenna contact is oriented with respect to the lead so that said  
10 connector increases coupling of radio frequency energy received by the  
antenna circuit into said radio frequency circuit chip.
  
2. The packaged radio frequency circuit in accordance with claim 1,  
wherein said radio frequency circuit chip comprises a radio frequency  
15 identification integrated circuit chip.
  
3. The packaged radio frequency circuit in accordance with claim 1,  
wherein the lead and said connector have similar cross-sections to provide a  
smooth transition of a radio frequency wave to the antenna contact.
  
- 20 4. The packaged radio frequency circuit in accordance with claim 1,  
wherein said connector is a wire bond.
  
5. The packaged radio frequency circuit in accordance with claim 1,  
25 wherein said package includes a second lead and said radio frequency circuit  
chip includes a second antenna contact, and wherein the packaged radio  
frequency circuit comprises a second connector disposed within said package  
for interconnecting the second lead and the second antenna contact.
  
- 30 6. The packaged radio frequency circuit in accordance with claim 5,  
wherein said radio frequency circuit chip and connectors are oriented within said

package so that coupling of a radio frequency signal into the radio frequency circuit chip is increased.

7. The packaged radio frequency circuit in accordance with claim 5,  
5 wherein the first lead extends from a first side of said package and the second lead extends from a second side of said package opposite the first side.

8. The packaged radio frequency circuit in accordance with claim 5,  
wherein the first and second leads extend from the same side of said package.

10

9. The packaged radio frequency circuit in accordance with claim 5,  
wherein the first lead extends from a first side of said package and the second lead extends from a second side of said package, and wherein the first and second leads are positioned one on each side of a corner of the package at a  
15 substantially right angle to each other.

10. The packaged radio frequency circuit in accordance with claim 5,  
wherein the leads and said connectors have similar cross-sections to provide a smooth transition of a radio frequency wave to the antenna contact.

20

11. The packaged radio frequency circuit in accordance with claim 3,  
wherein said connectors are wire bonds.

25

12. A radio frequency identification transponder, comprising:  
an insulating substrate;  
an antenna circuit formed as an integral part of said substrate, said antenna circuit including an antenna; and  
a packaged radio frequency identification integrated circuit further comprising:  
a lead frame package having at least one lead for coupling the packaged  
30 radio frequency circuit to said antenna circuit;

a radio frequency circuit chip contained within said lead frame package,  
said circuit chip including an antenna contact; and  
a connector connecting the antenna contact and lead;  
wherein the antenna contact is oriented with respect to the lead so that  
5                   said connector increases coupling of radio frequency energy  
                  received by the antenna into said radio frequency circuit chip.

13. The radio frequency identification transponder in accordance with  
claim 12, wherein the radio frequency circuit chip and connector are oriented  
10               within the package so that coupling of a radio frequency signal from the antenna  
                  into the circuit chip is optimized.

14. The radio frequency identification transponder in accordance with  
claim 13, wherein the lead and connector have similar cross-sections to provide  
15               a smooth transition of a radio frequency wave from the antenna to the antenna  
                  contact of the radio frequency circuit chip.

15. The radio frequency identification transponder in accordance with  
claim 12, wherein the connector is a wire bond.  
20

16. The radio frequency identification transponder in accordance with  
claim 12, wherein the package includes a second lead and said radio frequency  
circuit chip includes a second antenna contact positioned adjacent to the second  
lead, and wherein the packaged radio frequency identification integrated circuit  
25               comprises a second connector disposed within said package for interconnecting  
                  the second lead and the second antenna contact.

17. The radio frequency identification transponder in accordance with  
claim 16, wherein the radio frequency circuit chip and connectors are oriented  
30               within the package so that coupling of a radio frequency signal from the antenna  
                  into the circuit chip is increased.

18. The radio frequency identification transponder in accordance with claim 16, wherein the first lead extends from a first side of the package and the second lead extends from a second side of the package opposite the first side of  
5 the package.

19. The radio frequency identification transponder in accordance with claim 16, wherein the first and second leads extend from the same side of the package.

10

20. The radio frequency identification transponder in accordance with claim 16, wherein the first lead extends from a first side of the package and second lead extends from a second side of the package, and wherein the first and second leads are positioned one on each side of a corner of the package at  
15 a substantially right angle to each other.

21. The radio frequency identification transponder in accordance with claim 16, wherein the leads and connectors have similar cross-sections to provide a smooth transition of a radio frequency wave from the antenna to the  
20 antenna contact of the radio frequency circuit chip.

22. The radio frequency identification transponder in accordance with claim 12, wherein the connectors are wire bonds.

25 23. The radio frequency identification transponder in accordance with claim 12, wherein said radio frequency circuit chip is oriented on said substrate so that the surface area of said substrate is minimized.

30 24. The radio frequency identification transponder in accordance with claim 12, wherein said substrate includes an aperture, and wherein said packaged radio frequency integrated circuit is substantially and operably located

within the aperture so that the lead extends from the aperture and is interconnected to said antenna circuit.

25. The radio frequency identification transponder in accordance with  
5 claim 12, wherein said packaged radio frequency integrated circuit is oriented on  
the substrate so that coupling of a radio frequency signal from the antenna into  
the radio frequency circuit chip is increased.

26. A packaged radio frequency circuit, comprising:  
10 a lead frame package having first and second leads for coupling the packaged  
radio frequency circuit to an antenna circuit;  
a radio frequency circuit chip contained within said lead frame package, said  
radio frequency circuit chip including first and second antenna contacts;  
a first connector connecting the first antenna contact to the first lead;  
15 a second connector connecting the second antenna contact to the second lead;  
wherein the first antenna contact is oriented with respect to the first lead and the  
second antenna contact is orientated with respect to the second lead so  
that the first and second antenna contacts, the first and second  
connectors and the first and second leads maximize coupling of radio  
20 frequency energy received by the antenna into the radio frequency circuit  
chip.

27. The packaged radio frequency circuit in accordance with claim 26,  
wherein the first lead extends from a first side of said package and the second  
25 lead extends from a second side of said package opposite the first side.

28. The packaged radio frequency circuit in accordance with claim 26,  
wherein the first and second leads extend from the same side of said package.

30 29. The packaged radio frequency circuit in accordance with claim 26,  
wherein the first lead extends from a first side of said package and the second

lead extends from a second side of said package, and wherein the first and second leads are positioned one on each side of a corner of the package at a substantially right angle to each other.

5        30.      The packaged radio frequency circuit in accordance with claim 26, wherein the leads and said connectors have similar cross-sections to provide a smooth transition of a radio frequency wave to the antenna contact.

10      31.      The packaged radio frequency circuit in accordance with claim 26, wherein said connectors are wire bonds.

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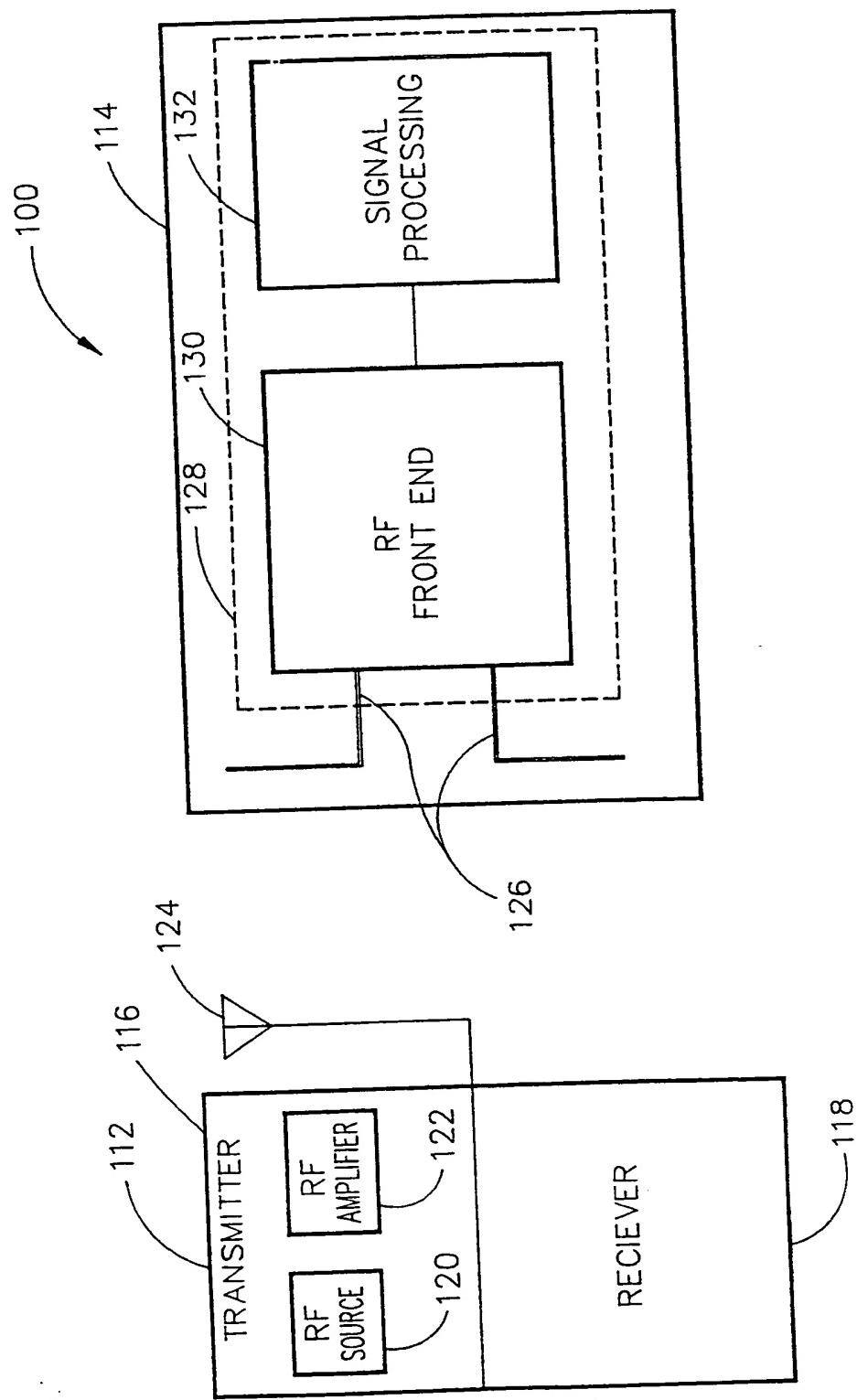


FIG. 1

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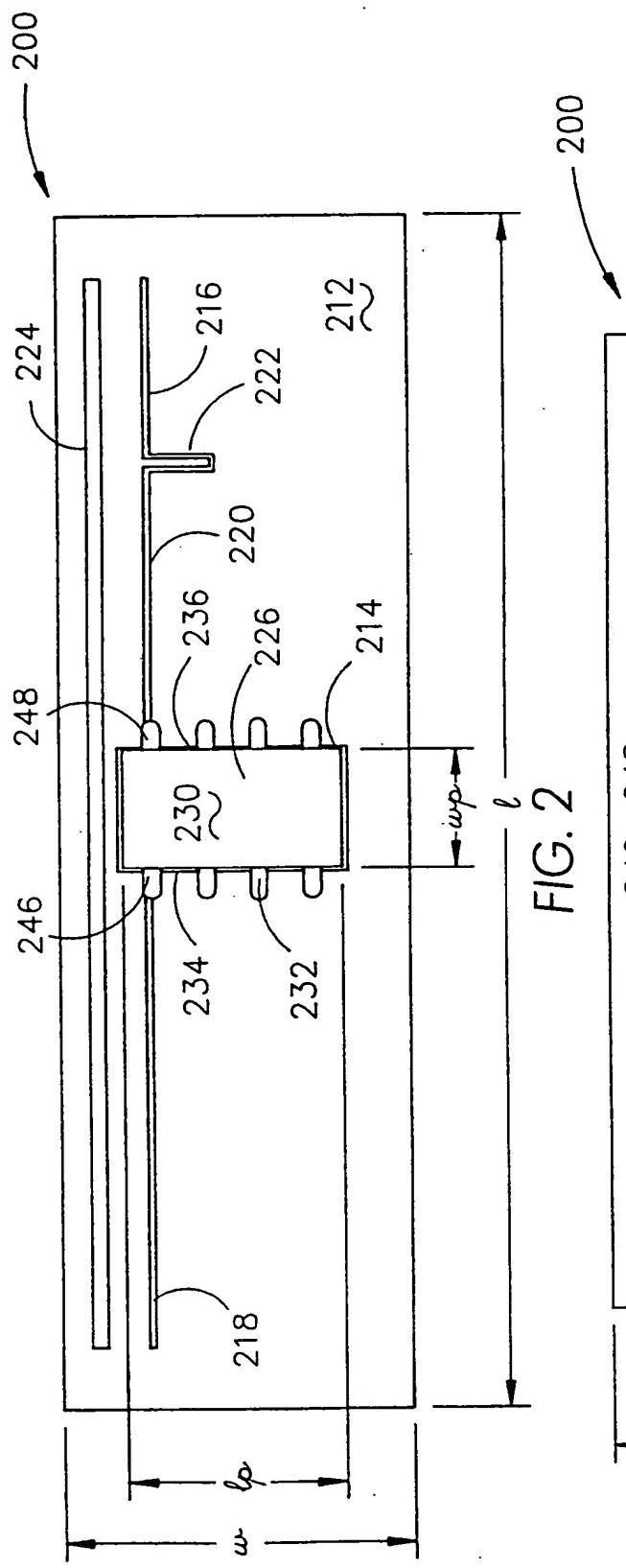


FIG. 2

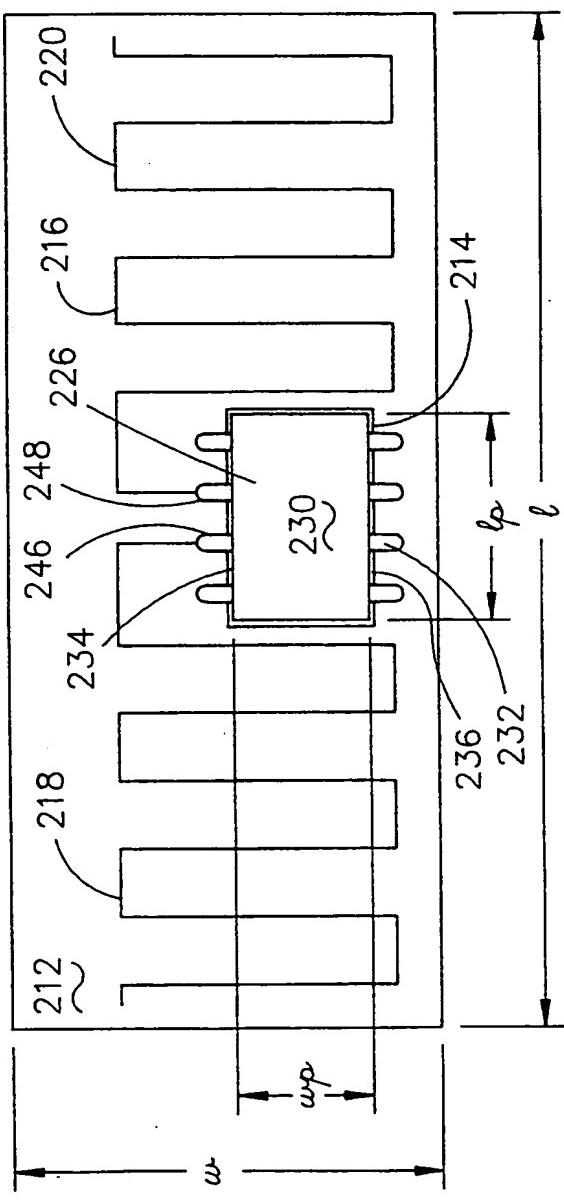


FIG. 3

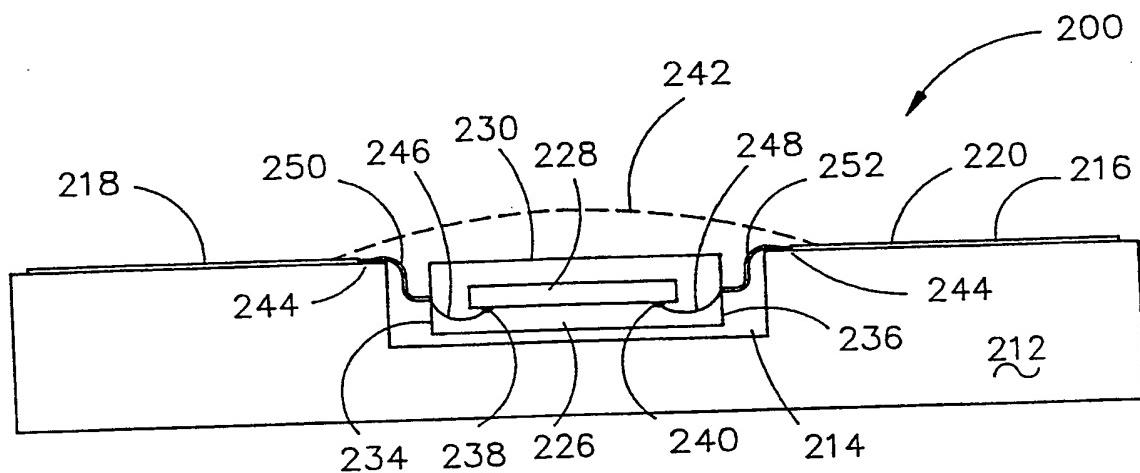


FIG. 4

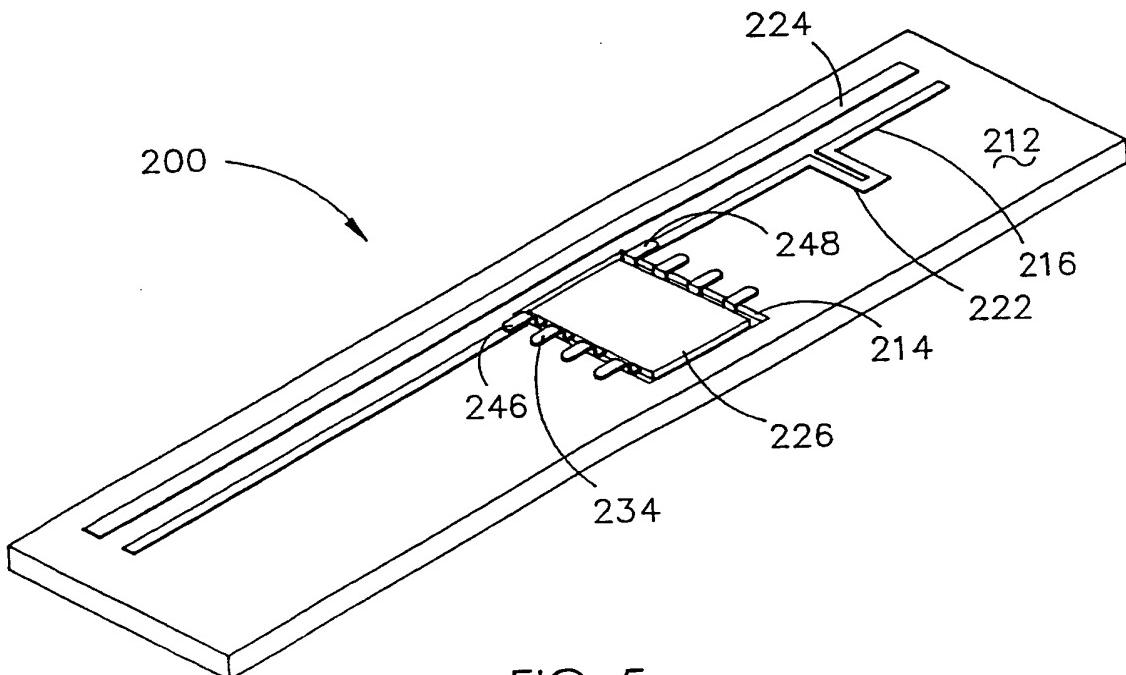


FIG. 5

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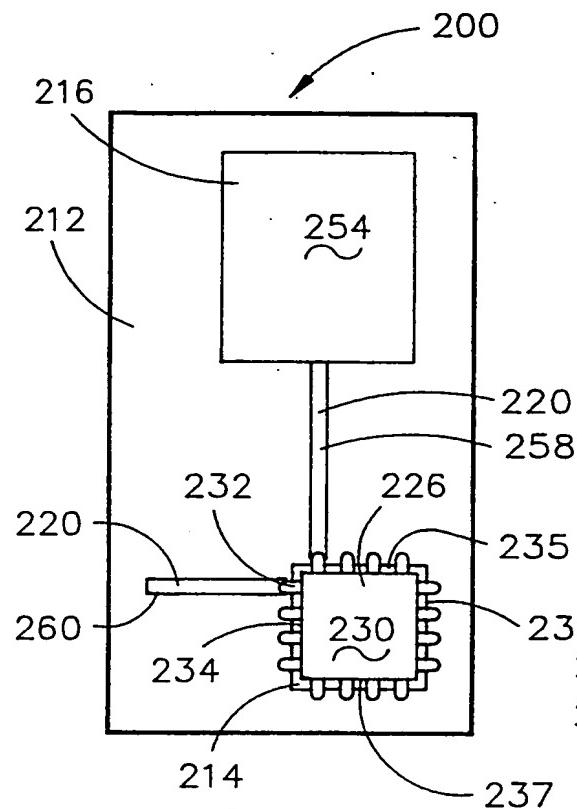


FIG. 6

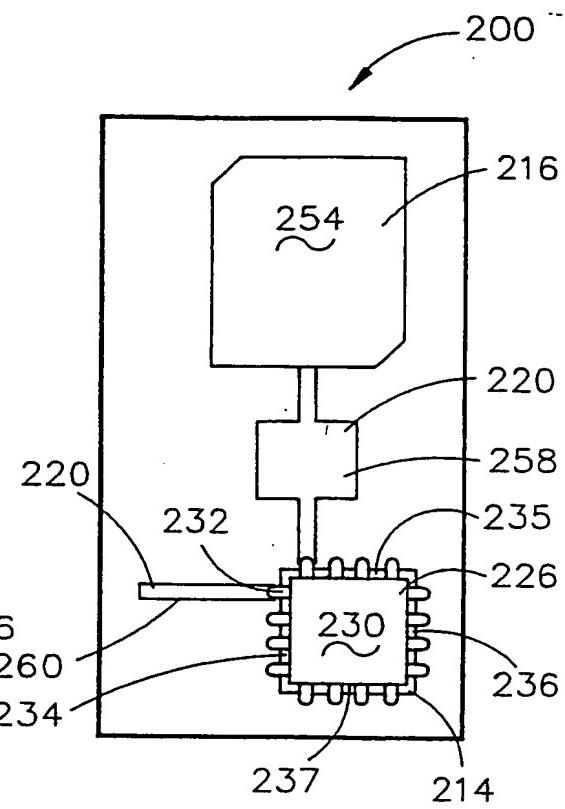


FIG. 7

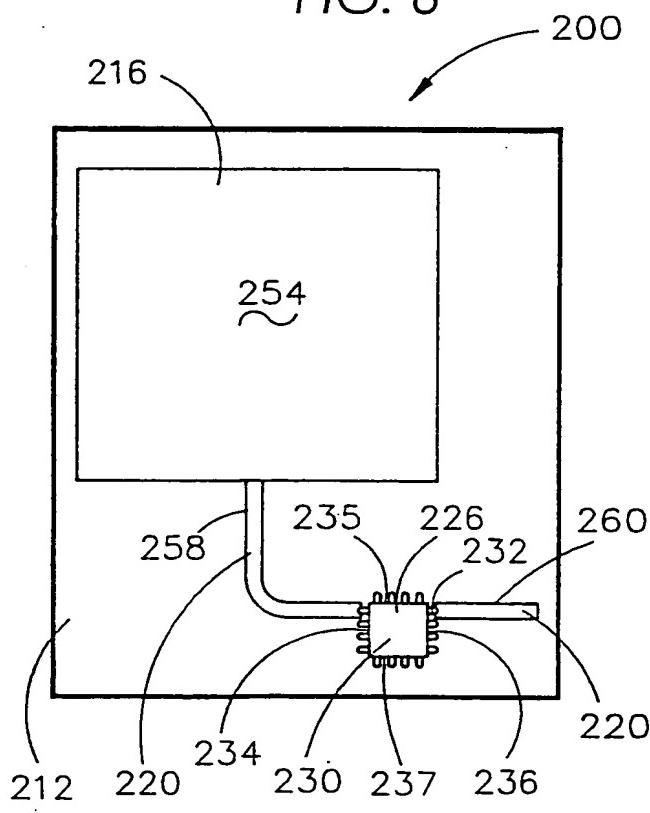


FIG. 8

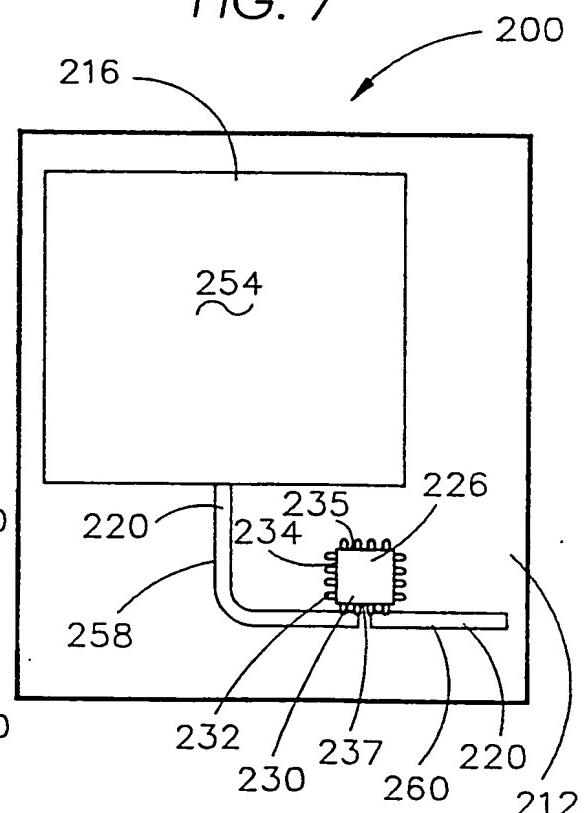


FIG. 9

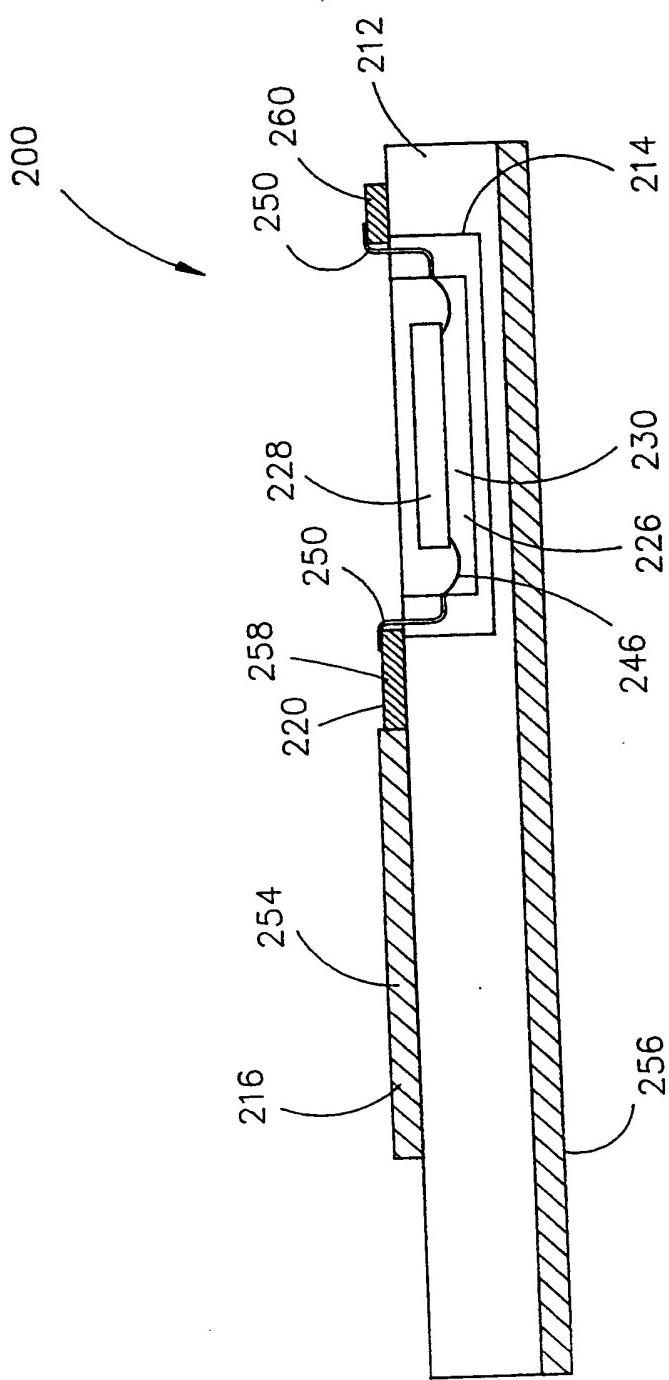


FIG. 10

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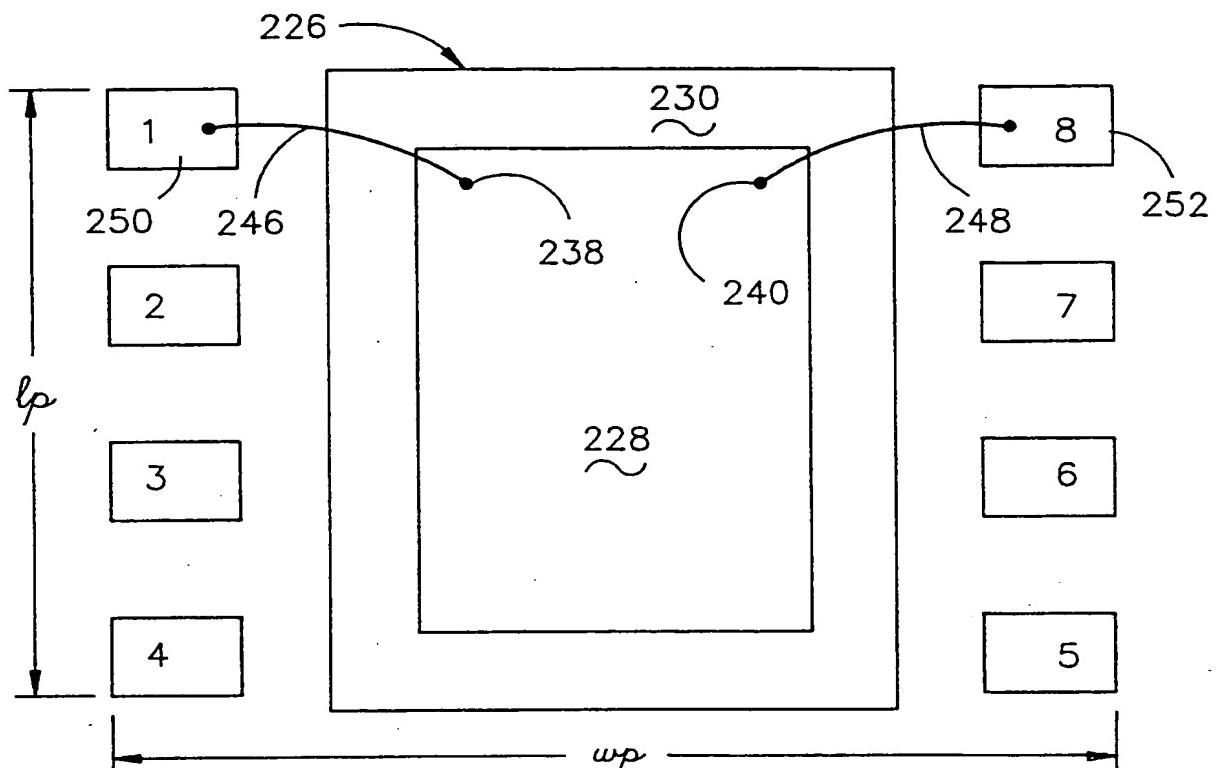


FIG. 11

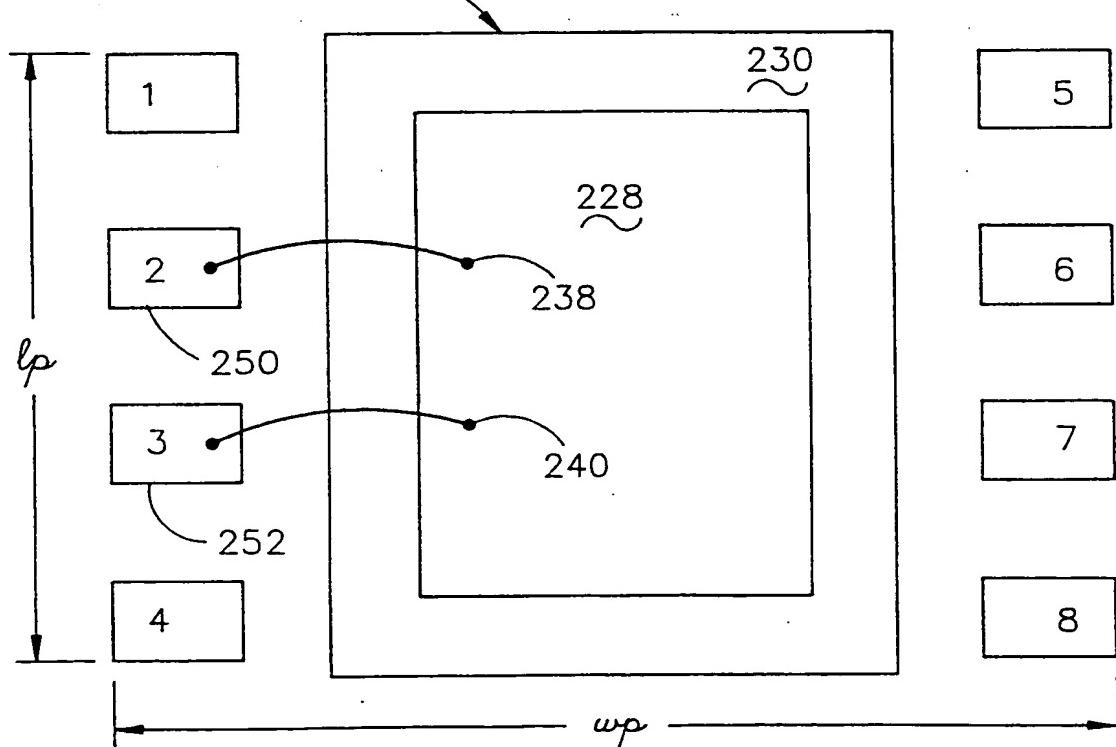


FIG. 12

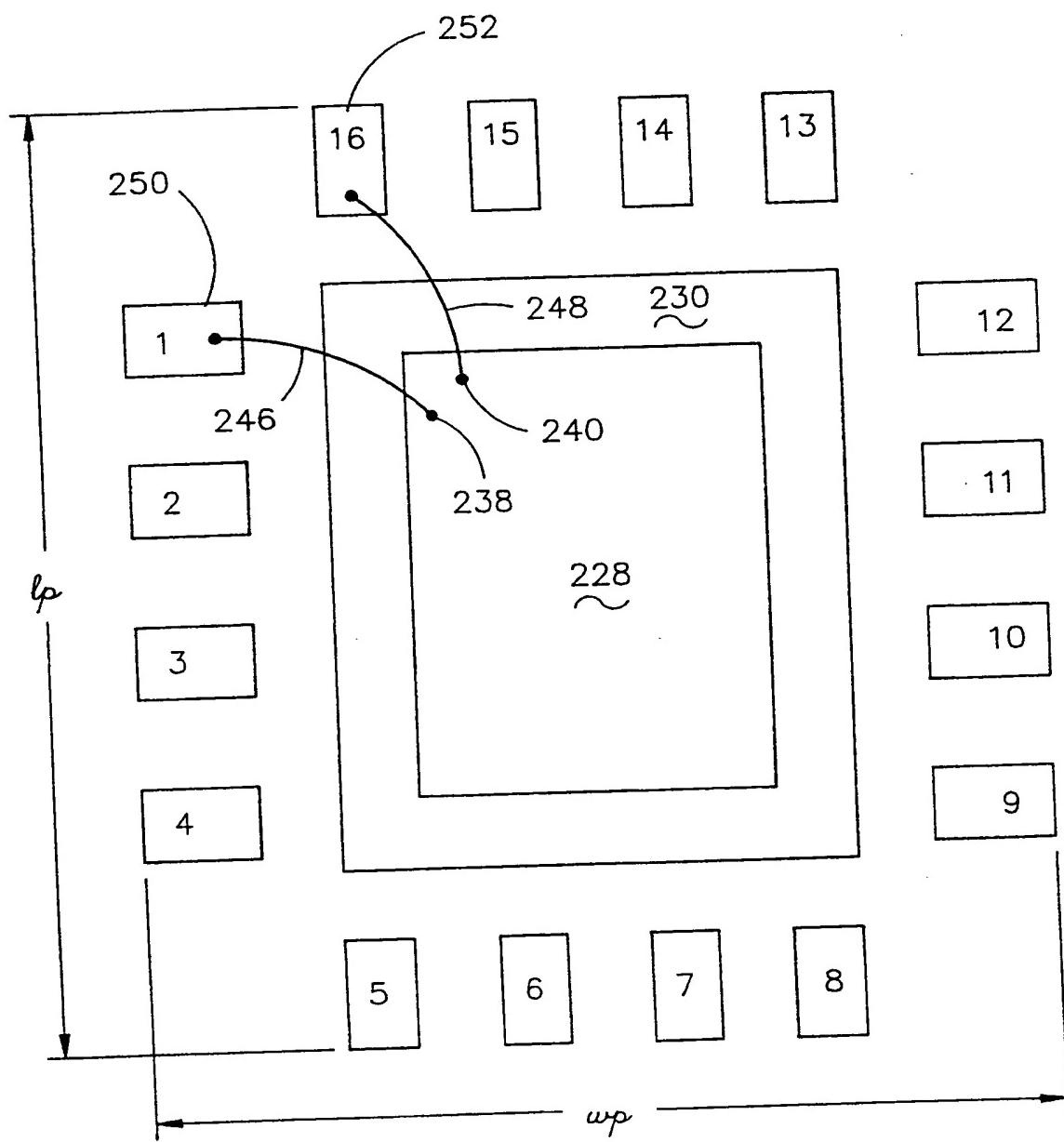


FIG. 13

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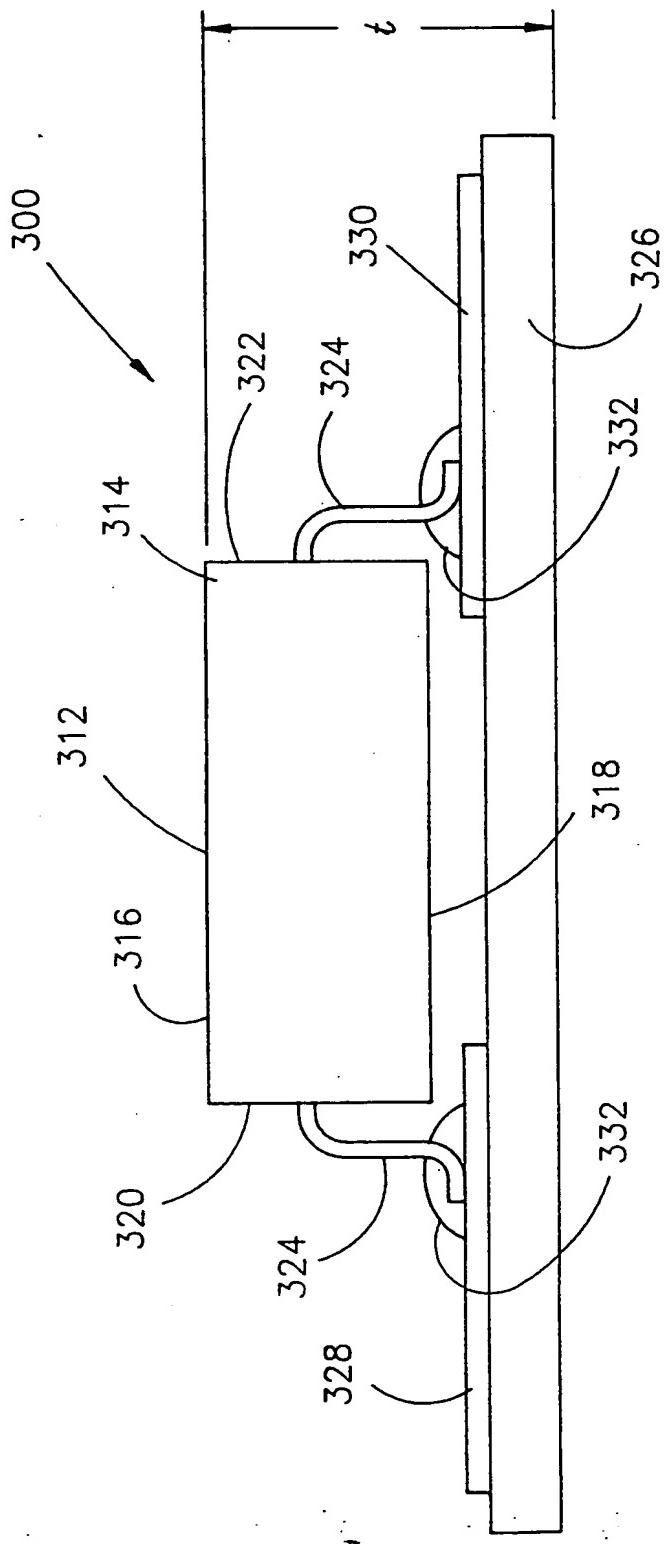


FIG. 14  
(PRIOR ART)

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/02042

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 G06K19/077

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G06K H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 44 31 754 C (SIEMENS AG) 23 November 1995 (1995-11-23)	1,2,4-9, 12-23, 25-29,31 24
Y	the whole document	24
Y	EP 0 756 244 A (GIESECKE & DEVRIENT GMBH) 29 January 1997 (1997-01-29) column 6, line 45 -column 7, line 11; figures 5A,5B	
X	DE 197 03 057 A (PAV CARD GMBH ;SIEMENS AG (DE)) 2 July 1998 (1998-07-02)  the whole document	1,2,4-9, 12-23, 25-29,31
		-/-



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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\*&\* document member of the same patent family

Date of the actual completion of the international search

12 May 2000

Date of mailing of the international search report

26/05/2000

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## INTERNATIONAL SEARCH REPORT

Int. Jpn Application No

PCT/US 00/02042

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International Application No

PCT/US 00/02042

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